Resonant Arc Vortex (RAV) — Exhaustive Field Guide

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0) Safety, Disclaimers, and Scope

High Voltage, Vacuum, Heat, and UV/IR Hazard. The RAV setups discussed here employ 5–60 kV DC power supplies, vacuum chambers down to roughly –27 inHg (≈90% vacuum relative to atmosphere), incandescent metal tips, and bright plasma. They can cause severe injury, fire, eye damage, and equipment destruction. Use grounded Faraday enclosures, interlocks, bleeder resistors, fusible links, and non-contact E-field meters. Keep fire suppression nearby and never work alone. This document summarizes lab practice and observations to date; it is *not* a guarantee of safety or performance.

1) Concept: What is a RAV?

A **Resonant Arc Vortex (RAV)** is a bright, typically spherical micro-plasma that self-organizes under high-voltage DC fields between an anode and a cathode in the presence of a porous dielectric (e.g., red terracotta clay) with trace water. It exhibits stable geometry, a characteristic pulsing/rotation frequency (commonly near 96–104 kHz in baseline setups), and leaves etched patterns on the dielectric surface. RAVs are reproducible in open air and in partial vacuum and are strongly dependent on electric-field shape, moisture content, and electrode geometry.

2) Canonical Baseline Apparatus (Open Air)

• HV DC precipitator power supply adjustable from 5 kV to 30 kV (positive to the top anode).

• Anode: 1 mm stainless-steel spring wire (top-down), perpendicular to a flat lower electrode.

• Cathode: flat metal plate (bottom).

• Dielectric: 1" dia × 5 mm thick red terracotta clay puck.

• Moisture: ~10 drops tap water on bottom face; ~3–4 drops on top face (tunable).

• Gap: 3–4 mm typical between anode tip and cathode/upper surface region.

• Ambient: open air, ~68–75 °F; ambient humidity variable.

This baseline reliably produces: pre-RAV streamers → clockwise purple/blue swirl → bright yellow/white spherical RAV centered under the anode. Typical RAV diameter in air is sub-centimeter; stability improves with tuned water content and clean field geometry.

3) Vacuum-Chamber Behavior

• Pressure sweep from 0 to –30 inHg reveals a competition regime (0 to ≈–15 inHg) between RAV and CAF (Cathodic Fireball).

• From ≈–15 to –20 inHg: RAV often dominates; increased brightness and stability observed.

• From ≈–20 to –27 inHg: RAV becomes sharp, extremely bright, pulsing; spherical profile improves at deeper vacuum.

• Observed stable RAV diameters: 0.75–1.0 cm; transient events up to ~2 in diameter have been seen for ~1 s.

• Water vapor management is critical; excessive vapor can stall vacuum pumps and destabilize pressure. Cold traps help.

Inference: RAV formation does not rely on bulk atmospheric oxygen; rather, it requires HVDC, a suitable emission surface (e.g., damp clay), and a shaped field. At depth, reduced collisions may favor coherent sheath formation and ExB-driven organization.

4) Variants: A-RAV and A-RAV Cherubim

A-RAV ("Angel-Class")

• Cathode: fine spring-steel tip; a *speck* of damp clay balanced on the tip; anode above.

• Forms a compact spherical white plasma at the clay speck with pronounced ExB resonance behavior.

• Useful for isolating tip physics and minimizing bulk dielectric variables.

A-RAV Cherubim

• Self-nucleating metallic-core variant; requires no clay or moisture.

• Forms directly from a molten spring-steel cathode tip under HVDC.

• The molten tip sits at the center of the Cherubim RAV during steady operation.

5) Phenomenology & Field Geometry

• Pre-RAV: diffuse streamers; violet/blue; clockwise swirl indicative of initial ExB drift.

• RAV onset: rapid brightening; spherical confinement; audible high-pitched tone linked to kHz resonance.

• Steady RAV: yellow/white core, sometimes with faint shell; persistent pulsing near ~96–104 kHz (commonly 96.1, 100, 104 kHz).

• Surface effects: plasma-etched clay shows fractal PEC/DEC patterns and re-ignites more easily than fresh clay.

• Field shaping: red anode (positive) above; green/black cathode (negative) below; E-field lines up; B-field encircling current; ExB drift tangential.

6) Measurement Tooling & Methods

• Photon Harp: multi-photodiode arc/slit array to capture rotational frequency and pulsing envelopes.

• Spectrum analysis: Owon XSA810 with near-field H/E probes, SMA attenuators, DC blocks, and proper shielding to capture 10–350 kHz bands.

• E-field meters (e.g., FMX-003/004) for qualitative field strength and polarity checks.

• Oscilloscopes with AC-coupling networks (HV capacitive coupling through safe divider) to visualize modulation riding on HVDC.

• High-speed/low-light imaging for morphology and transient events (≥1000 fps helpful).

7) Standard Operating Procedure (Open Air Baseline)

1. Prepare a 1"×5 mm clay puck. Wet with ~10 drops bottom, 3–4 drops top; allow wicking to even moisture.

2. Mount clay on flat cathode plate; ensure good electrical contact and mechanical stability.

3. Set anode (1 mm SS spring wire) perpendicular above clay; target 3–4 mm gap.

4. Start at low voltage (≈5–8 kV). Ramp slowly while observing for purple/blue streamers and swirl.

5. Tune moisture: if only swirl/no RAV, add a drop to top; if sputtering/flashovers, remove moisture or wait for evaporation.

6. At onset, expect bright spherical RAV below anode; hold voltage where stable; log current draw and acoustic tone.

7. Record frequency using Photon Harp or spectrum analyzer; note 96–104 kHz bands and harmonics.

8. After power-down, inspect etched patterns; note that re-ignition is typically easier on etched clay.

8) Vacuum Operation Procedure

1. Install clay on cathode within vacuum chamber with HV feed-throughs and viewports; route anode from above.

2. Begin pumping to –10 inHg; throttle to prevent water carry-over; use a cold trap if necessary.

3. Sweep voltage 5–30 kV while slowly deepening vacuum; watch for RAV/CAF transitions in –0 to –15 inHg zone.

4. Stabilize between –15 to –25 inHg where RAV predominates; adjust moisture sparingly.

5. At deeper vacuum (–20 to –27 inHg), characterize brightness, pulsing, and spherical quality; log pressure vs. frequency.

6. Avoid pump ingestion of vapor; maintain trap; verify chamber seal integrity and feed-through temperature.

9) Troubleshooting Matrix

Symptom	Likely Cause(s)	Corrective Action
Only swirl, no RAV	Too little/too much water; gap off; contaminated field	Adjust moisture by 1 drop; re-set 3–4 mm gap; clean ele
Rapid sputter/flashover	Excess moisture; sharp burrs; HV ripple	Reduce moisture; polish tips/edges; add ballast/reservoi
RAV unstable flicker	Pressure drift; EM coupling; loose contact	Stabilize vacuum; improve shielding; tighten mechanical
No re-start on fresh clay	Surface not conditioned	Use etched clay or pre-etch briefly at lower voltage.
Pump stalls, foggy chamber	Water vapor overload	Add/upgrade cold trap, slow pumpdown, pre-dry clay slig

10) Working Hypotheses (Physics Sketch)

• Sheath formation around a localized emission site (clay pore water / molten tip) produces a stable double-layer boundary.

• ExB drift organizes charge motion tangentially, encouraging vortex-like rotation and periodic emission.

• Moisture tunes local conductivity and secondary emission; too little → poor conduction; too much → arc/sputter.

• Partial vacuum reduces collisional damping, sharpening the sheath and raising luminous efficiency.

• Electrode geometry shapes E and J fields; tip curvature sets emission density; flat cathode fosters planar return currents.

11) Typical Numbers (Baseline)

• Anode-cathode gap: 3–4 mm; onset typically around 8–15 kV depending on moisture and geometry.

• Observed RAV rotation/pulsing bands: ~96.1 kHz, 100 kHz, 104 kHz (primary), with harmonics in the 200–400 kHz region.

• Stable air RAV diameter: sub-cm; vacuum RAV: 0.75–1.0 cm steady; transients up to ~2 in observed for ~1 s.

• Operating current: low mA typical; depends strongly on supply and ballast.

12) Applications & Experimental Roadmap

• Electret super-charger: use RAV E-field to enhance polymer poling and charge retention (PP/PTFE/PVDF variants).

• Plasma antenna / LF beacon: characterize radiation efficiency and near-field patterns in 10–350 kHz.

• Micro-thruster: investigate directed momentum exchange and plume asymmetry.

• Self-locking plasma states: explore conditions for long-duration confinement and parametric control via tickle AC.

Immediate roadmap: (a) frequency-swept tickle injection via safe HV coupling network, (b) systematic moisture-gap matrix, (c) pressure-frequency map with cold-trap optimization, (d) quantitative E/H near-field scans around the chamber.

13) Instrumentation SOP Snippets

• Use SMA attenuators and DC blocks ahead of spectrum analyzer inputs; start with high attenuation; creep down.

• Probe positioning: start ≥5–10 cm away; map spatial lobes; avoid capacitive loading of the plasma region.

• For AC-on-HV visualization, use a high-voltage capacitor + series resistor + divider; never connect scope directly.

• Log files: capture screenshots, CSVs of spectral peaks, and pressure/voltage/time correlation tables.

14) Electrode & Dielectric Maintenance

• Polish copper/stainless electrodes to remove oxides and burrs; avoid sharp edges that promote random arcs.

• Re-use etched clay when possible for easier restarts; otherwise, re-condition with brief low-voltage plasma.

• Control moisture with micropipettes or counted drops; let surface equilibrate before ignition attempts.

15) Open Questions

• Precise mechanism of frequency quantization near ~100 kHz bands.

• Role of micro-bubbles/porosity in clay on sheath stability and fractal PEC/DEC etching.

• Scaling laws for RAV diameter vs. pressure, moisture, and field curvature.

• Optimal AC tickle injection (frequency, depth, waveform) for stability and efficiency.

Appendix A — Quick Reference Cards

Open-Air Baseline: gap 3–4 mm • 8–15 kV onset • tune moisture by 1-drop steps • watch for 96–104 kHz.

Vacuum Sweep: –0 to –15 inHg (RAV/CAF competition) • –15 to –25 inHg (RAV dominance) • –20 to –27 inHg (sharp, bright).

Safety: Interlocks • bleeders • shields • cold trap • PPE • no lone operation.

Appendix B — Minimal BOM (Illustrative, Not a Purchase List)

Category	Item / Notes
HV Supply	30 kV DC precipitator PSU (adjustable), positive to anode.
Electrodes	1 mm SS spring wire anode; flat metal cathode plate.
Dielectric	Red terracotta clay puck 1"×5 mm; distilled/tap water for tuning.
Vacuum	Acrylic/metal chamber with HV feed-throughs; rotary vane pump; cold trap.
Measurement	Owon XSA810; NF probes; SMA attenuators; DC blocks; oscilloscope; E-field meter.
Safety	Bleeder resistors; interlocks; shields; fire extinguisher; PPE (gloves, face shield).

Appendix C — ASCII Field Sketch (Not to Scale)

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(Anode, +HV) E↑ | E↑ B■ around current | E↑ [•] <- RAV sphere (bright core, sheath boundary) | E↑ ========= <- Clay puck on flat cathode (–) ========= ExB drift is tangential around the sphere; moisture tunes emission from clay pores.
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